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Title: AUTOMATED TELEPHONE LINE TEST APPARATUS WITH
INTELLIGENT DIAGNOSTIC FUNCTION

Inventors: ROBERT J. LYSAGHT, DONALD FINGER,
JEFFREY HAHN, ANTHONY M. KOLODZINSKI,
HOWARD CITRON, YU-LING WU

AUTOMATED TELEPHONE LINE TEST APPARATUS WITH
INTELLIGENT DIAGNOSTIC FUNCTION

FIELD OF THE INVENTION

5 This invention relates to portable apparatus for use
in testing telephone lines from subscriber locations.

BACKGROUND OF THE INVENTION

10 It is known to provide portable equipment to be used
by telephone company technicians in trouble-shooting
telephone lines on which trouble is reported. It is also
known to use microcomputer technology, including a keypad-
responsive processor and a processor-controlled display, to
15 aid the technician in using line-test equipment and as an
interface for outputting information from the line-test
equipment.

 An example of portable line-test equipment which
employs microcomputer technology for input and output is
the CMC 7910DX DataStar 386 terminal and test module
20 (hereinafter "DataStar 386"), sold by Communications
Manufacturing Co., Los Angeles, California. The "Generic
User's Manual" for the DataStar 386, published by
Communications Manufacturing Co., is incorporated herein by
reference.

25 It is an object of the invention to provide a portable
telephone line test device that is easier to use than prior
art devices.

 It is a further object of the invention to provide a
telephone line test device which automatically carries out
30 a standardized sequence of tests.

 It is still a further object of the invention to
provide a telephone line test device which interprets
results of tests performed by the device and automatically
diagnoses sources of line troubles on the basis of the test
35 results.

It is yet another object of the invention to provide a telephone line test device which displays interpretive messages and instructions to the user.

SUMMARY OF THE INVENTION

5 In accordance with the principles of the present invention, objects noted above and other advantages are realized by provision of an automated telephone line test apparatus including test circuitry for applying test signals to a telephone line to be tested and for detecting
10 electrical characteristics of the telephone line, a processor connected to the test circuitry for controlling the test circuitry, a display connected to the processor, and a program memory connected to the processor, the processor being programmed to control the test circuitry so
15 that the test circuitry performs a pre-programmed sequence of tests, the pre-programmed sequence of tests being performed in accordance with a program stored in the program memory and the processor also being programmed to control the display such that the display provides a
20 sequence of indications each corresponding to a respective test of the pre-programmed sequence of tests, each indication being displayed while the corresponding test is being performed.

 According to another aspect of the invention, there is
25 provided an automated telephone line test apparatus, including test circuitry for applying test signals to a telephone line to be tested and for detecting electrical characteristics of the telephone line, the test circuitry having capabilities of performing a plurality of tests that
30 are different from each other, a processor connected to the test circuitry for controlling the test circuitry and for receiving test results from the test circuitry, a program memory connected to the processor, and a program stored in the program memory, the program causing the processor to
35 cause the test circuitry to perform a first one of the

plurality of tests, and the program also causing the processor to select a second test from the plurality of tests on the basis of a result of a first one of a plurality of tests.

5 According to a further aspect of the invention, there is provided an automated telephone line test apparatus which includes test circuitry for applying test signals to a telephone line to be tested and for detecting electrical characteristics of the telephone line, a processor
10 connected to the test circuitry for controlling the test circuitry, a display connected to the processor and a program memory connected to the processor, the processor being programmed to control the test circuitry so that the test circuitry performs a test with respect to the
15 telephone line; the processor further being programmed to receive data from the test circuitry indicative of a result of the test and, according to the result of the test, to control the display to display a message instructing a user of the apparatus to perform a second test with respect to
20 a cable which includes the telephone line to be tested.

 According to still another aspect of the invention there is provided an automated telephone line test apparatus which includes test circuitry for applying test signals to a telephone line to be tested and for detecting
25 electrical characteristics of the telephone line to be tested, a processor connected to the test circuitry for controlling the test circuitry, a display connected to the processor and a program memory connected to the processor, the processor being programmed to control the test
30 circuitry so that the test circuitry performs a test with respect to the telephone line to be tested, the processor further being programmed to receive data from the test circuitry indicative of a result of the test and, according to the result of the test, to control the display means to

display a string of alphabetic characters which informs a user of the apparatus of the result of the test.

According to still a further aspect of the invention, there is provided an automated telephone line test apparatus which includes test circuitry for applying test signals to a telephone line to be tested and for detecting electrical characteristics of the telephone line, the test circuitry including a plurality of test leads for being selectively connected to the telephone line, a processor connected to the test circuitry for controlling the test circuitry, a display connected to the processor and a program memory connected to the processor, the processor being programmed to control the display to display a message instructing a user of the apparatus to change a connection between the test lead and the telephone line to be tested.

The test apparatus provided in accordance with the invention carries out a complete and standardized troubleshooting operation without relying on a high level of knowledge on the part of the test technician. An effective and consistent diagnostic procedure is programmed into the apparatus. The test sequence is adapted according to the test results and the likely source of trouble indicated by the test results. The technician is guided step by step through the test procedure and is provided with information that helps the technician to understand the process carried out by the apparatus and the meaning of the test results. The technician receives comprehensive indications of the test results, and recommendations for corrective action.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features, advantages and aspects of the present invention will become more apparent upon reading the following detailed description in conjunction with the accompanying drawings in which:

Fig. 1 is a high-level block diagram of a test apparatus provided in accordance with the invention;

Fig. 2 is a block diagram of a user interface module that is part of the apparatus of Fig. 1;

5 Figs. 3, 3A, 3C are flow charts which illustrate a software program for controlling a microprocessor that is part of the user interface module of Fig. 2;

Fig. 3B illustrates operations at a central office in connection with an automatic line identification function;
10 and

Figs. 4-11 illustrate various screen displays provided by the user interface module of Fig. 2.

DETAILED DESCRIPTION

15 A preferred embodiment of the invention is implemented as a software enhancement of a conventional device, such as the above-referenced DataStar 386 device. An overview of a suitable hardware environment for implementation of the invention is provided by Figs. 1 and 2. In Fig. 1, a test
20 device 10 in accordance with the operation is shown to include a test module 12 and a user interface module 14. The test module 12 has test leads 16 suitable for connection to tip, ring and ground sides of the telephone line to be tested. The test module and user interface
25 module may respectively correspond to the test module and terminal portions of the DataStar 386 device. It is also contemplated to integrate the test module and user interface module into a single unit.

Fig. 2 illustrates salient components of the user
30 interface module 14, which preferably is arranged in accordance with a standard architecture for a microcomputer. Included in the module 14 are a microprocessor 18, a working memory 20 associated with the microprocessor 18, a program memory 22 which stores a
35 program for controlling operation of the microprocessor 18,

a keyboard 24 by which a user provides input to the microprocessor 18, and a display 26 by which the microprocessor provides output to the user. Also included in the module 14 are an interface 28 through which the
5 microprocessor 18 exchanges signals with the test module 12, and a communications interface 30 through which the microprocessor 18 can exchange data with a remote device such as a host computer.

Operation of the apparatus 10 to perform telephone
10 line trouble-shooting will now be discussed, initially with reference to Fig. 3. Fig. 3 illustrates in flow-chart form a program stored in the program memory 22 which causes the apparatus to carry out an adaptive diagnostic test sequence. The diagnostic function illustrated in Fig. 3
15 may be selected by the user from a main menu (not shown) displayed on the display 26. Selection of the process of Fig. 3 from the menu is indicated at initial step 32 of Fig. 3. In response to selection of the diagnostic function, a screen display like that shown in Fig. 4 is
20 provided by the display 26. The screen display of Fig. 4 includes a number of fields, including job ID fields indicated at 42, a field 44 which lists specific tests that may be carried out by the apparatus, and test result data fields 46, 48 and 50. Included at a bottom part of the
25 display of Fig. 4 is a message field 52. Upon initialization of the diagnostic function, the message in the message field 52 instructs the user to connect some of the test leads 16 to appropriate sides of the telephone line to be tested. The user can then initiate the
30 diagnostic procedure.

At the beginning of the diagnostic procedure, as indicated at block 34 in Fig. 3, the test apparatus performs a test to determine whether the cable which contains the telephone line to be tested is satisfactorily
35 grounded. Block 36 in Fig. 3 indicates that the test

procedure branches depending on whether satisfactory grounding is found. If so, the apparatus proceeds to perform basic tests to determine whether basic functions are available in the telephone line to be tested (block 5 54). Specifically, standard tests are performed for AC and DC voltage, and loop current. On the basis of these tests, it is determined whether basic line function is present on the telephone line being tested (block 56). If so, a sequence of transmission characteristic tests are performed (block 58). If at block 56 basic line function was not found, then the procedure of Fig. 3 advances from block 56 to block 60, at which tests are performed to detect hard shorts or grounds. In a preferred embodiment, these tests include detecting resistance levels among tip, ring and ground connections. Block 62 of Fig. 3 indicates that the procedure branches, according to whether a hard short or ground is detected with respect to the tip and ring connections. If so, the location of the fault is determined (block 64). Otherwise, tests are performed to gather more information about a "soft" fault or open circuit condition (block 66). Preferably these tests include a capacitive "kick" test and a stress test. In all cases, as indicated by block 68, results of the various tests are indicated on the display 26.

Referring again to block 36, a finding of "bad ground" at that point leads the apparatus 10 to give the user the opportunity to reattach the ground lead to the telephone cable and to retest for adequate ground (block 38). If the user elects to do so, the procedure loops back to blocks 34 and 36. Otherwise, the procedure branches to a curtailed test sequence (Fig. 3A) in which the apparatus only performs tests that can provide meaningful results in the absence of satisfactory grounding. In this case, as indicated by block 154 of Fig. 3A, the same voltage and current tests are performed as were mentioned above in

connection with block 54. Then, the procedure branches (block 156) according to whether basic line function is found. If so, block 158 follows, in which the two-wire loss and circuit noise tests are performed. Power
5 influence, balance and stress tests are omitted, since valid results cannot be obtained without good ground. If at block 156 basic line function was not found, a test for a tip-ring short circuit is performed (block 160). After either of blocks 156 and 158, the test results are reported
10 to the user (block 68, Fig. 3).

Referring once more to Fig. 3, after the sequence of tests represented by block 58 are performed, the apparatus carries out a procedure to confirm, by machine-to-machine contact, that the telephone line that has just been tested
15 matches the line indicated by the job assignment. This line confirmation process is represented by block 69 in Fig. 3, and will now be described with reference to Figs. 3B and 3C.

Referring initially to Fig. 3B, the test apparatus
20 requests identification of the telephone line under test by dialing up a line identification facility provided in the central office (block 102.). That is, the test apparatus couples onto the telephone line under test pre-determined dialing signals which correspond to the telephone number
25 (dialing no.) of the central office line i.d. facility. These dialing signals are received at the central office, which treats the dialing signals as a request to identify the telephone line on which the dialing signals are received (block 104 Fig. 3C). The central office then
30 generates DTMF (dual tone multi-frequency) signals which represent the telephone number (dialing number) of the telephone line on which the request was received (block 106). The central office couples the DTMF signals to the requesting telephone line for transmission to the test
35 apparatus (block 108).

Referring again to Fig. 3B, the apparatus receives the DTMF signals transmitted from the central office (block 110), and decodes the DTMF signals to produce data which indicates the telephone number corresponding to the telephone line under test. There follows block 112, at which the apparatus retrieves from memory 20 (Fig. 3) data which identifies the telephone number of the telephone line which is the intended subject of the work assignment (e.g., the telephone line on which trouble was reported). It will be understood that the work assignment data, including the number of the line to be tested, had previously been stored before commencing the test procedure. The apparatus then compares the telephone number data retrieved from memory with the telephone number data obtained by decoding the DTMF signals from the central office, to confirm that the line actually tested was the one intended to be tested according to the work assignment.

This machine-to-machine work assignment confirmation procedure represents an advance over prior art practice, in which the test technician dialed up the central office telephone line i.d. facility, and then listened to an audible verbal response, generated via speech synthesis by the central office equipment, which stated the line number of the tested line. The prior practice required the technician to match the number given by the machine-generated speech with the work assignment data specifying the line intended to be tested. The machine-to-machine confirmation procedure of Figs. 3B and 3C relieves the technician of the effort of carrying out line i.d. confirmation, while enabling the test apparatus to automatically store data confirming that the line tested was in fact the line which was the intended subject of the test assignment.

Further details of the program illustrated in Fig. 3 will be understood from the pseudo-code listing annexed

hereto as Appendix I, and from the script file printouts annexed hereto as Appendix II. In addition, the following discussion will highlight aspects of the adaptive nature of the diagnostic functions of the test apparatus 10, and particularly the guidance and information provided to the user by the apparatus.

TEST SEQUENCE EXAMPLE--NO TROUBLE FOUND

Initially, it will be assumed that the telephone line to be tested is operating in accordance with prescribed specifications in all respects. This may occur, for example, if there is an error in reporting trouble on the line, or if the line is being tested to confirm successful completion of a trouble shooting and repair operation that has already been performed with respect to the telephone line. In any case, once the diagnostic function has been started, the ground, AC voltage, DC voltage and loop current tests are performed as called for by block 54 in Fig. 3. According to the present assumption, all of those tests indicate proper functioning of the telephone line, so that the apparatus proceeds to a sequence of transmission characteristic tests represented by block 58, including a two-wire circuit loss test, a circuit noise test, a power influence test, a longitudinal balance test, and a stress test. It is to be understood that each of these individual test procedures is a standard test which is well known to those of ordinary skill in the art, and therefore need not be described in detail. As the sequence of tests represented by blocks 54 and 58 is being performed, the apparatus provides to the user indications of what the apparatus is doing at any given time. For example, the apparatus may display an indication mark such as ">" in the test sequence field 44 to indicate that the apparatus is progressing through the sequence of tests. Specifically, when the AC voltage tests is being performed, the ">" may be positioned adjacent the words "AC Volts" in field 44.

When that test is complete, the indicator ">" would be moved downward so as to be adjacent to the words "DC Volts". The indicator ">" would be positioned adjacent the corresponding words in Fig. 44 as each test in the sequence is performed, concluding with the word "Stress" as the stress test was being performed at the end of the transmission characteristic tests of Fig. 58. In addition, as results were obtained for each of the tests, the fields 46, 48 and 50 would be populated with corresponding test data obtained by carrying out the respective test. In addition, the progress through the sequence of tests is reflected by verbal messages provided in the message field 52. For example, when the AC voltage test has been completed and the DC voltage is being carried out, a message such as the following may be displayed in the message field 52:

"AC Voltage tests complete. Met
acceptable values: TR, TG & RG < 5 vAC."

20

In addition, the following text may also be displayed:

"DC voltage test now being performed."

25 Following is a sequence of messages displayed in the message field 52 as the sequence of tests proceeds through steps 54 and 58, and satisfactory results are found throughout.

Initially, after the ground test has been performed,
30 the message displayed is:

"Ground test complete. Found good
ground. Met acceptable range: TR < 70
dBrnC. Connect the ring lead (red)
35 before continuing."

Then, when the ring lead has been connected, the apparatus performs the AC voltage test and on completing the test the following message is displayed:

5 "AC voltage tests complete. Met
 acceptable values: TR, TG & RG < 5 vAC."

Then the DC voltage test would be performed, and upon completion the following message displayed:

10 "DC voltage tests completed. Met
 acceptable values: TR & RG = 48-52 vDC
 and TG = 0 vDC."

15 As the above tests are completed, in addition to displaying the messages indicated above, the fields 46, 48 and 50 are populated in the appropriate rows with data corresponding to the actual test results.

20 The sequence of tests continues, and after completion of the loop current test, the following message is displayed:

 "Loop current test completed. Met
 acceptable range: TR = 23-65 mA."

25 Since the voltage, current and ground tests all indicated acceptable readings, the two-wire circuit loss test is performed next. Upon completion of the test with acceptable readings, the following message is displayed.

30 "Circuit loss test completed. Met
 acceptable range: TR < 8.5 dBm."

The next test is the circuit noise test. Upon satisfactory completion of this test the following message is displayed.

5 "Circuit noise test completed. Met
 acceptable range: TR < = 20 dBrnC."

Then the power influence test would be performed, and upon completion the following message displayed:

10 "Power influence test completed. Met
 acceptable range: TR < 90 dBrnC."

The next test to be performed is the longitudinal
15 balance test. Upon completion of that test, the following
message is displayed:

 "Longitudinal balance completed. Met
 acceptable range: TR > = 60 dBrnC."
20

The final test in the sequence is the stress test. Upon completion of this test, the screen display of Fig. 5 would be provided. In the message field 52, completion of the test is indicated as well as finding of acceptable
25 results. It will be noted that the fields 46, 48 and 50 have been fully populated with data indicating the results of the tests that have been performed. It will also be noted that, at the bottom of the message field 52, the user is advised that the test sequence has been completed and
30 the user's options are presented. Fig. 5A is a screen which indicates that the apparatus has performed the automatic line number confirmation procedure described above in connection with Figs. 3B and 3C.

35

EXAMPLES WITH TROUBLE FOUND

If during the sequence of tests an unacceptable reading is found, a corresponding message is provided in the message field 52. An example of such a message is shown in Fig. 6, which shows the message provided when the stress test results in an unacceptable reading. Other messages indicative of unacceptable conditions are listed in Appendix II.

As has been discussed above, if basic line function is not found at steps 54 and 56 (Fig. 3), testing for a hard fault takes place. Fig. 7 illustrates a screen display provided when a hard fault is found. The tests for which unacceptable readings were obtained are marked with an asterisk in field 44 (in this example the "DC Volts" and "Ohms" test entries are so marked) and entries in fields 46, 48 and 50 indicative of readings outside of the acceptable range are highlighted. (In this example, the highlighted out-of-range data are the entries in field 46 (tip-ring) corresponding to the DC volts and Ohms tests, and the entry in field 50 (ring-ground) corresponding to the DC volts test.)

If a hard fault is found, an additional field 70 collects the data required to calculate the distance to the fault. A message in field 52 prompts the user to enter the required data. The "coils" entry is for indicating whether load coils are present on the cable. A pop-up list (not shown) prompts the user to enter the number of load coils. Entries for the wire gauge are also provided. Based on the entered data, an estimated distance to the fault is calculated and displayed, as shown in Fig. 7A. The user also has the option to change some of the parameters and have the distance calculation repeated.

When the test sequence is complete, the user is permitted to direct the apparatus to retest the line.

Alternatively, the user may view the test results obtained, or may exit from the automated diagnostic function.

Fig. 8 shows an example of a screen display provided when the user elects to view test results. In this case, it is assumed that a hard fault (tip-ring short) has been found and the estimated distance to fault calculated.

Figs. 9, 10 and 11 are other examples of screen displays provided in response to the selection of the "view test results" function. Fig. 9 illustrates an initial screen display of previously determined test results in which acceptable results are shown. The screen display of Fig. 10 may be reached by scrolling down from the display of Fig. 9. In the example shown in Fig. 10, a lack of DC voltage is indicated.

Fig. 11 is another example of a screen viewable through the "view test results" option. In this case, the two-wire circuit loss test resulted in an unacceptable reading.

Another notable feature of the present invention resides in instructions provided by the apparatus to the user to engage in additional tests in certain circumstances.

For example, if the ground test carried out by the apparatus fails to find good ground, the apparatus displays the message, "Check for breaks in ground conduit." Also, if the stress test carried out by the apparatus provides a marginal reading, the apparatus displays the message:

"One-sided fault (imbalance) may be forming. Check a good pair to see if stress reading is typical for this area -
- marginal outside plant."

As another example, if the "kick" test performed as part of block 66 (Fig. 3) indicates a two-sided open condition, the user is instructed:

5 "Check a good pair to verify kick values
 indicate an open condition. The stress
 test will be done next, to test for
 electrical balance."

10 It has been noted above that, during the course of the
 test sequence carried out by the apparatus, the apparatus
 instructs the user to change the configuration of the
 connection between the test leads and the line being
 tested. For example, after detection of adequate ground,
15 the user is instructed to connect the ring lead to the ring
 side of the line. However, according to another embodiment
 of the invention, the user may be instructed to connect all
 three test leads respectively to tip, ring and ground at
 the beginning of the test sequence. This embodiment is
20 further provided with suitable relays or other switches in
 the test module that are controlled to effectively control
 connection or disconnection of the lead within the test
 module.

 It should also be noted that, in a preferred
25 embodiment of the invention, the apparatus displays a
 reminder to the user that when a new line is to be tested,
 the test leads must be disconnected from the previous line
 and connected to the new line.

 The portable telephone line testing apparatus
30 disclosed herein provides significant advantages in terms
 of aiding telephone technicians in the performance of line
 trouble-shooting operations. The apparatus provides
 automated selection and sequencing of test procedures and
 diagnosis of trouble on the basis of test results. The
35 apparatus also keeps the technician informed as the test

sequence proceeds, test results are obtained, and diagnostic conclusions reached. The technician is provided with step-by-step guidance as to actions needed to continue the test procedure and with recommendations for remedial
5 actions. The apparatus is programmed to provide consistent and effective trouble-shooting procedures which make efficient use of the technician's time and minimize call-backs on trouble reports.

Also, in accordance with conventional practice, the
10 portable line-test apparatus may be connected by telephone line with a central administrative computer, so that job assignment data may be downloaded to the apparatus from the central computer. In addition, test result data and other reports on jobs performed can be uploaded to the central
15 computer from the portable line-test apparatus. The uploaded data may include a list of the tests for which satisfactory and unsatisfactory results were founded, as well as the actual test data where the results were unsatisfactory. Also, the data uploaded by the apparatus
20 may include a confirmation that the line number provided by the central office during the procedure of Figs. 3B and 3C matched the number of the line specified in the work assignment. If there was not a match, the number of the line actually tested may be reported.

25 In all cases it is understood that the above-described arrangements are merely illustrative of the many possible specific embodiments which represent applications of the present invention. Numerous and varied other arrangements can be readily devised in accordance with the principles of
30 the present invention without departing from the spirit and scope of the invention.